

INVESTIGATIONS OF NANOCOOLANT BASED Al_2O_3 FOR IMPROVING COOLING PERFORMANCE IN HOT PRESS FORMING

LIM SYH KAI

MASTER OF SCIENCES

UNIVERSITI MALAYSIA PAHANG



SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science in Manufacturing Engineering.

(Supervisor's Signature)

Full Name : IR. DR. AHMAD RAZLAN BIN YUSOFF

Position : ASSOCIATE PROFESSOR

Date : 23 MAY 2018



STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

(Student's Signature)

Full Name : LIM SYH KAI

ID Number : MMF15007

Date : 23 MAY 2018

INVESTIGATIONS OF NANOCOOLANT BASED Al_2O_3 FOR IMPROVING
COOLING PERFORMANCE IN HOT PRESS FORMING

LIM SYH KAI

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Science

Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

MAY 2018

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest appreciation to all those who provided me the possibility to complete this master degree research. This project would not have been possible generous assistance, cooperation and support of a number of people.

A special gratitude goes to my supervisor, Assoc. Prof. Ir. Dr. Ahmad Razlan bin Yusoff, who contributed significantly stimulating suggestions, continuous encouragement, valuable guidance and advices. His professional supervision and support truly help the progression and smoothness of my project in which his co-operation is highly appreciated.

My sincere appreciation goes to my lab mates, Ms. Norlida binti Jamil, Mr. Mohd Fawzi bin Zamri and Ms. Nik Nurul Husna binti Muhmed Razali for their continuous support. Besides, a million thanks to Assoc. Prof. Dr. Abdul Aziz bin Jaafar, Dr. Zamzuri bin Hamedon and Ms. Law Hoon Chit in sharing knowledge and ideas generously and giving me helping hands to resolve my doubts in research jobs. Also, I would like to convey my gratefulness to laboratory assistants, Mr. Aidil Shafiza bin Safiee, Mr. Shahandzir bin Baharom and Mr. Mohd Nursyazwan bin MD Talip for the guidance in using the testing equipment.

Last but not least, I acknowledge my sincere indebtedness and gratitude to my lovely family for their continuous support, encouragement and sacrifice throughout my life. A special thanks to my parents who consistently encouraged me to pursue my studies to a higher education level as well as with their mental and physical support, their tolerance of my ignorance and naïve mistakes.

ABSTRAK

Pembentukan kepingan keluli panas (HPF) untuk membangunkan UHSS boron keluli untuk panel badan dalaman kenderaan menawarkan penggunaan bahan api yang efisien untuk mengurangkan pelepasan gas karbon dioksida oleh pengurangan berat badan dan meningkatkan keselamatan penumpang kerana sifat mekanikal yang tinggi. Boron keluli dipanaskan sehingga suhu austenitik dan kemudian disejutkan dengan cepat dalam sebuah acuan dalam masa pelindapkejutan tertentu untuk mempamerkan fasa transformasi martensit. Pada masa ini, air digunakan sebagai cecair penyejuk dalam proses HPF untuk menghilangkan keluli boron dalam sebuah acuan tertutup dengan saluran bendalir penyejukan. Walau bagaimanapun, untuk meningkatkan prestasi acuan HPF dan meningkatkan sifat mekanikal boron keluli ditekan panas, bendalir dengan sifat termal yang lebih baik akan digunakan dan bukannya air biasa. Semasa operasi pelindapkejutan, kadar cecair penyejukan optimum dan pengagihan suhu homogen pada kekosongan panas ke arah pencapaian transformasi mikrostruktur martensitic serta sifat mekanikal yang tinggi. Kajian ini menyebarkan nanopartikel Al_2O_3 dari kepekatan isipadu sebanyak 0.2 hingga 1.0% dengan purata diameter 13 nm ke dalam tiga peratusan air ke etilena glikol seperti 60%:40%, 50%:50%, dan 40%: 60% dengan menggunakan kaedah penyediaan dua langkah. Kedua-dua parameter utama dalam prestasi kadar cecair penyejukan adalah kekonduksian terma dan kelikatan dinamik. Pengedaran pemindahan haba pekali panas dengan nanocoolant dan air sejuk disimulasikan untuk analisis haba sementara dalam simulasi unsur terhingga melalui ANSYS untuk menilai peningkatan pekali pemindahan haba konveksi dan menentukan kadar cecair penyejukan optimum bendalir penyejukan sistem dalam acuan HPF. Data simulasi kemudian dibandingkan dengan penemuan eksperimen untuk tujuan pengesahan. Telah didapati bahawa peningkatan kekonduksian terma tertinggi adalah 10% lebih tinggi daripada bendalir asas untuk kepekatan volum 1,0% Al_2O_3 pada 55 °C dalam 60%:40% (W/EG). Walau bagaimanapun, peningkatan kelikatan dinamik yang paling tinggi diukur sebanyak 39% untuk kepekatan volum 1.0% Al_2O_3 dalam 40%:60% (W/EG) pada 25 °C. Koefisien pemindahan haba konveksi kepekatan 1.0% dalam 60%:40% (W/EG) pada 25 °C ditingkatkan dengan 25.4% lebih baik daripada 50%:50% dan 40%:60% (W/EG) cecair. Oleh itu, kajian ini memperakukan penggunaan Al_2O_3 dalam campuran 60%:40% (W/EG) dengan kepekatan volum Al_2O_3 kurang daripada 1.0% untuk aplikasi dalam saluran bendalir penyejukan acuan HPF. Itu juga terbukti bahawa corak pengedaran suhu model analisis unsur terhingga bersesuaian dengan hasil eksperimen. Kekuatan tegangan dan nilai kekerasan Vickers bahagian yang ditekan panas dinilai masing-masing kira-kira 1,550 MPa dan 588 HV. Sebagai kesimpulan, nanocoolant sebagai cecair penyejuk dengan pekali pemindahan haba konveksi yang lebih tinggi berbanding dengan air sejuk boleh mengurangkan masa pelindapkejutan dalam proses HPF.

ABSTRACT

Hot press forming (HPF) to develop UHSS of boron sheet metals for vehicle inner body panels offers efficient fuel consumption in order to reduce carbon dioxide gas emissions by weight reduction and improves passenger safety because of its high mechanical properties. The sheet metal is heated up to austenitic temperature and then rapidly quenched in an enclosure dies in a certain quenching time to exhibit martensitic transformation phase. Currently, water is used as coolant in the HPF process to quench boron steels in a closed die with a cooling channel. However, to enhance the performance of HPF dies and increase the mechanical properties of hot pressed boron steel, the fluid with better thermal properties will be used instead of normal water. During the quenching operation, an optimum cooling rate and homogeneous temperature distribution on hot blanks towards the achievement of the martensitic microstructure transformation as well as high mechanical properties. This study dispersed Al_2O_3 nanoparticles from the range of 0.2 to 1.0% volume concentration with an average diameter of 13 nm into three volume percentages of water to ethylene glycol such as 60%:40%, 50%:50%, and 40%:60% by using the two-step preparation method. The two main parameters in cooling rate performance are thermal conductivity and dynamic viscosity. The heat transfer distribution of the hot blanks with nanocoolant and chilled water are simulated for transient thermal analysis in finite element simulation via ANSYS to evaluate the enhancement of convection heat transfer coefficient and determine the optimum cooling rate of cooling system in HPF tool. The simulation data were then compared with experimental findings for validation purpose. It was found that the highest enhancement of thermal conductivity was observed to be 10% higher than base fluid for 1.0% volume concentration of Al_2O_3 at 55 °C in 60%:40% (W/EG). However, the highest enhancement of dynamic viscosity was measured to be 39% for 1.0% volume concentration of Al_2O_3 in 40%:60% (W/EG) at 25 °C. The convective heat transfer coefficient of 1.0% concentration in 60%:40% (W/EG) at 25 °C is enhanced by 25.4% better than that of 50%:50% and 40%:60% (W/EG) base fluid. Therefore, this study recommends the use of Al_2O_3 in 60%:40% (W/EG) mixture with volume concentration of Al_2O_3 less than 1.0% for application in cooling channel of HPF dies. It was also evident that the pattern of the temperature distribution of the finite element analysis model was in agreement with the experimental results. The tensile strength and Vickers hardness values of the hot pressed parts were evaluated to be approximately 1,550 MPa and 588 HV, respectively. In conclusion, nanocoolant as cooling fluid with higher convection heat transfer coefficient compared to the chilled water can reduce the quenching time of HPF process.

TABLE OF CONTENT

DECLARATION

TITLE PAGE

ACKNOWLEDGEMENTS **ii**

ABSTRAK **iii**

ABSTRACT **iv**

TABLE OF CONTENT **v**

LIST OF TABLES **ix**

LIST OF FIGURES **x**

LIST OF SYMBOLS **xiii**

LIST OF ABBREVIATIONS **xiv**

CHAPTER 1 INTRODUCTION **1**

1.1 Background of Study 1

1.2 Problem Statement 4

1.3 Objectives 6

1.4 Scope of Study 6

1.5 Hypothesis 8

1.6 Thesis Organisation 8

CHAPTER 2 LITERATURE REVIEW **11**

2.1 Introduction 11

2.2 Background of Nanofluids as Coolant 12

2.3 Properties of Water-Ethylene Glycol Based Nanocoolants 13

2.4	Nanoparticles as Suspended Material	15
2.4.1	Nanoparticle materials	17
2.4.2	Types of synthesized nanofluids	19
2.5	Nanofluids Preparation	20
2.6	Thermal Properties of Nanofluids	22
2.6.1	Dynamic viscosity	23
2.6.2	Thermal conductivity	25
2.7	Sheet Metal of Boron Steel	27
2.8	Hot Press Forming Process	30
2.8.1	Heating operation	32
2.8.2	Forming operation	36
2.8.3	Punching and loading force	38
2.9	Heat Transfer Mechanism	40
2.9.1	Tools temperature and contact pressure	41
2.9.2	Cooling Channel Design for Fluid Flow Types	44
2.10	Finite Element Thermal Analysis in Hot Press Forming	46
2.11	Summary	52
CHAPTER 3 METHODOLOGY		54
3.1	Introduction	54
3.2	Materials and Preparation of Nanocoolants	56
3.3	Thermal Conductivity Measurement	60
3.4	Dynamic Viscosity Measurement	62
3.5	Finite Element Analysis	64
3.5.1	Thermal analysis	66
3.5.2	Geometric modelling of hat-shaped tools	68

3.5.3	Boundary conditions and constraint parameters	69
3.5.4	Meshing	70
3.5.5	Numerical simulation	72
3.6	Experimental Approach of Hot Press Forming	74
3.6.1	Sample preparation	76
3.6.2	Location of thermocouples	77
3.6.3	Hot press forming of boron steel sheet metal	78
3.6.4	Experimental study of heat transfer distribution	80
3.6.5	Tensile test measurements	83
3.6.6	Micro-hardness measurements	85
3.6.7	Metallographic observation study	86
3.7	Summary	88
CHAPTER 4 RESULTS AND DISCUSSION		89
4.1	Introduction	89
4.2	Thermal Physical Properties	90
4.2.1	Thermal conductivity of nanocoolant	90
4.2.2	Dynamic viscosity of nanocoolant	94
4.2.3	Heat transfer coefficient of nanocoolant	98
4.3	Thermal Analysis Results and Validation with Hat-Shaped Tools	101
4.3.1	Comparison of nanocoolant with chilled water in simulation	104
4.3.2	Temperature validation of hot press forming with thermal analysis	106
4.4	Experimental Analysis of Hot Pressed Boron Steel	107
4.4.1	Microstructural transformation analysis	107
4.4.2	Tensile strength analysis	111

4.4.3	Hardness analysis of hot formed boron steel	114
4.5	Summary	116
CHAPTER 5 CONCLUSION		118
5.1	Conclusion	118
5.2	Contributions to Knowledge	120
5.3	Future Works	121
REFERENCES		123
APPENDIX A G-code for cutting tensile test specimen from hat-shaped part		140
APPENDIX B Heat transfer coefficient values of nanocoolant		141
APPENDIX B1 Sample of cooling rate for heated sheet metal blank		142
APPENDIX C Sedimentation observation of aluminium oxide/water-EG mixture after a month of preparation		143
APPENDIX D Sample of tensile strength and hardness measurement		145
List of publication		146

LIST OF TABLES

Table 2.1	Thermo-physical property of different types of metal and liquid	13
Table 2.2	Various types of nanoparticles and micrograph images	17
Table 2.3	Types of nanoparticles dispersed in nanofluids	20
Table 2.4	Dynamic viscosity investigations for different types of nanocoolants	24
Table 2.5	Thermal conductivity study for diverse types of nanofluids	26
Table 2.6	Chemical compositions of boron steel weight percentage and mechanical properties before and after quenching operation	28
Table 2.7	Thermal-physical properties of boron steel	29
Table 2.8	Stamping process in hot temperature conditions	39
Table 2.9	Results of contact pressure and standard deviation of HTC	42
Table 3.1	Properties of nanoparticles used in experiment	57
Table 3.2	Properties of Ethylene Glycol solution	58
Table 3.3	Thermal conductivity models for nanocoolant	62
Table 3.4	Dynamic viscosity models for nanocoolant	64
Table 3.5	Material properties of SKD 61 and 22MnB5 at room and hot temperature	67
Table 3.6	Boundary condition for thermal analysis simulation	69
Table 3.7	Results of three different meshing sizes for hat-shaped tool	72
Table 3.8	The features of mechanical press machine model OCP 80	79
Table 3.9	The features of hydraulic press machine	80
Table 3.10	Specifications of Universal Tensile Machine	84
Table 3.11	Specifications of Wilson Vickers 402 MVD machine	86
Table 3.12	Specification of LOM, Olympus BX51M machine	87
Table 4.1	Temperature distribution for HPF tools and heated blank	104
Table 4.2	Micrographs of boron steel blank with several quenching time periods	108
Table 4.3	Tensile strength value for several specimens of hot formed boron steel	111
Table 4.4	Hardness value for several specimens of hat-shaped boron steel	114

LIST OF FIGURES

Figure 1.1	Tensile strength between UHSS and typical sheet metal	1
Figure 1.2	Mechanical properties of boron steel before and after hot forming process	3
Figure 1.3	Thesis organisation	10
Figure 2.1	Freezing point and boiling point of water-EG mixture	14
Figure 2.2	One-step method technique	21
Figure 2.3	Two-step method technique	22
Figure 2.4	Graph of velocity pattern versus velocity	23
Figure 2.5	Temperature, time and transformation diagram of boron steel at various cooling rates	29
Figure 2.6	Direct hot forming process	30
Figure 2.7	Indirect hot press forming	31
Figure 2.8	Hat-shape profile bending operation	32
Figure 2.9	Various types of heating system (a) Roller hearth furnace, (b) Induction heating and (c) Electrical resistance heating	33
Figure 2.10	Induction heating operation (a) Schematics diagram of the customized induction furnace and (b) Variation of temperature curve as function of time for several feeding speed	34
Figure 2.11	Localize heating (a) Positioning two rectangular electrodes on the blank and the temperature distribution diagram; and (b) Result of punching load for different heating temperatures in shearing region	35
Figure 2.12	Forming Limit Diagram of B-pillar	36
Figure 2.13	Simulation of B-pillar in hot press forming process	37
Figure 2.14	Geometries of tools and steel sheet for hat-shape and V-shape	37
Figure 2.15	Degree of springback after V-shape bending with the relationship of temperature in (a) Bending region; and (b) Flange region	38
Figure 2.16	Hot forming process of UHSS sheet metal by using resistance heating	39
Figure 2.17	Relationship between the maximum stamping load and heating temperature of UHSS sheet metal	40
Figure 2.18	Experimental setup and instrument for heat transfer coefficient testing	42
Figure 2.19	Relation between HTC as function of contact pressure for different tool temperatures	43
Figure 2.20	Thermal contact resistance (a) Ideal thermal contact; (b) Actual thermal contact	43

Figure 2.21	Schematic diagram of hot press forming tool design	45
Figure 2.22	Schematic diagram of the quenching tool integrated with hot forming operation	45
Figure 2.23	Interactions between the effects of heat transfer, microstructural evolution and deformation	48
Figure 2.24	temperature changes in heat transfer analysis	49
Figure 2.25	Tool cooling performance between SKD 61 and HTCS 150 tool materials with same cooling channel parameter	50
Figure 2.26	Heat transfer distributions on the dies during quenching step took completely 20 s	51
Figure 2.27	Hot stamping with several holding times in dies	51
Figure 3.1	Flow chart of introducing nanocoolant as cooling medium for HPF process	56
Figure 3.2	FESEM result of dry Al ₂ O ₃ nanoparticles at X300,000 magnification	57
Figure 3.3	Al ₂ O ₃ nanocoolant immersed in ultrasonic bath heater	59
Figure 3.4	Nanocoolant samples of Al ₂ O ₃ /water-EG mixtures after a month of preparation	60
Figure 3.5	(a) Schematic diagram of thermal conductivity measurement; (b) Experiment setup for thermal conductivity measurement.	61
Figure 3.6	(a) Schematic diagram of dynamic viscosity measurement; (b) Experiment setup for dynamic viscosity measurement	63
Figure 3.7	Flow chart of thermal finite element analysis on HPF	66
Figure 3.8	Simulation starts from the steady-state and ends with the transient thermal analysis	67
Figure 3.9	Geometric modelling in ANSYS simulation software	68
Figure 3.10	Hat-shaped tool imported into ANSYS simulation software	69
Figure 3.11	Surface contact between sheet metal blank and dies	71
Figure 3.12	The grid distribution of Hat-shaped tool and blank	72
Figure 3.13	Temperature distribution of hot pressed blank by using nanocoolant from ANSYS simulation	74
Figure 3.14	The process sequences of HPF experimental analysis	75
Figure 3.15	Pre-forming process of hat-shaped samples	76
Figure 3.16	Thermocouples location in HPF tool (a) Schematic diagram (b) Three thermocouples in upper tool	78
Figure 3.17	Fabrication of hat-shape sample by using mechanical press machine, OCP 80	79
Figure 3.18	Hydraulic press machine used in hot forming operation	80
Figure 3.19	The experimental equipment setup for hot press forming tool	81

Figure 3.20	Hot press forming process flow of hat-shaped blank	82
Figure 3.21	Location of hot formed samples for tensile specimen, hardness test and microstructure analysis	84
Figure 3.22	Specimen for tensile strength test	84
Figure 3.23	Tensile strength measurement with Universal Tensile Machine	85
Figure 3.24	Hardness measurement with Vickers Micro-hardness Machine, Wilson Vickers 402 MVD	86
Figure 3.25	Microstructural analysis by using light optical microscopy machine	87
Figure 4.1	Variation of thermal conductivity enhancement as function of nanoparticles volume concentrations in W/EG mixture at 25 °C	91
Figure 4.2	Thermal conductivity of different nanoparticle concentrations for three different mixture of W/EG base fluids	94
Figure 4.3	Variation of viscosity ratio as fraction of nanoparticle volume concentrations in W/EG mixture at 25 °C	95
Figure 4.4	Viscosity of different nanoparticle concentrations for three different mixture of water-EG base fluids	98
Figure 4.5	Relationship between thermal conductivity as function of nanoparticles volume concentration for three different mixture base fluids	99
Figure 4.6	Distribution of heat transfer coefficient of 60%:40% water-EG mixture based Al ₂ O ₃ nanocoolant	101
Figure 4.7	Thermal analysis at steady state condition for HPF simulation	102
Figure 4.8	Transient thermal analysis for HPF simulation by introducing nanocoolant	103
Figure 4.9	Transient thermal analysis for HPF simulation by introducing chilled water	103
Figure 4.10	Heat transfer distribution between nanocoolant and chilled water for hat-shaped tool	105
Figure 4.11	Comparison of heat transfer distribution between FEA and experiments for hat-shaped tool	107
Figure 4.12	Ultimate tensile strength of blank samples at several cooling conditions	112
Figure 4.13	Vickers hardness reading HV1 with diamond shaped indent 50 µm	114
Figure 4.14	Hardness value of hot pressed samples at several cooling conditions	115

LIST OF SYMBOLS

A	Heat transfer area
B	Bending length
C_{bf}	Specific heat of base fluid
C_{nf}	Specific heat of nanocoolant
C_p	Specific heat of particle
D	Pipe length
dT	Temperature difference
dX	Differential length
E	Modulus elasticity
h	Heat transfer coefficient
k	Thermal conductivity
k_{bf}	Thermal conductivity of base fluid
k_{nf}	Thermal conductivity of nanocoolant
L	Length
Nu	Nusselt number
P	Loading force
Pr	Prandtl number
Pr	Prandtl number of nanocoolant
q	Heat transfer
Re	Reynolds number
s	Second
t	Thickness
T_1	Inlet temperature
T_2	Outlet temperature
T_b	Bulk temperature
T_f	Surrounding fluid temperature
T_s	Surface temperature
V	Velocity
μ	Dynamic viscosity
μ_{bf}	Dynamic viscosity of base fluid
μ_{nf}	Dynamic viscosity of nanocoolant
ω	Weight concentration
ϕ	Volume fraction
ρ	Density
ρ_{bf}	Density of base fluid
ρ_{nf}	Density of nanocoolant
ρ_p	Density of particle
ϕ	Volume concentration
ϕ_1	Initial volume concentration
ϕ_2	Final volume concentration

LIST OF ABBREVIATIONS

AHSS	Advanced High Strength Steel
Al ₂ O ₃	Aluminium Oxide
ASTM	American Society for Testing and Materials International
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BR	Base Ratio
CuO	Copper Oxide
EG	Ethylene Glycol
FESEM	Field Emission Scanning Electron Microscopy
FEA	Finite Element Analysis
FLD	Forming Limit Diagram
FCNT	Functionalised Carbon Nanotube
DIN EN ISO	German Institute European Standard
HTC	Heat Transfer Coefficient
HSS	High Strength Steel
HTCS	High Thermal Conductivity Tool Steel
HPF	Hot Press Forming
SKD	Hot Work Tool Steel
IUPAC	International Union of Pure and Applied Chemistry
LOM	Light Optical Microscopy
MWCNT	Multi-walled Carbon Nanotube
SEM	Scanning Electron Microscopy
SiC	Silicon Carbide
SiO ₂	Silicon Oxide
TEM	Transmission Electron Microscopy
UHSS	Ultra-High Strength Steel
UTM	Universal Tensile Machine
W	Water

REFERENCES

- Abbassi, Y., Talebi, M., Shirani, A. S. and Khorsandi, J. (2014). Experimental investigation of TiO₂/water nanofluid effects on heat transfer characteristics of a vertical annulus with non-uniform heat flux in non-radiation environment. *Annals of Nuclear Energy*, 69, 7-13.
- Abdul-Hay, B., Bourouga, B. and Dessain, C. (2010). Thermal contact resistance estimation at the blank/tool interface: experimental approach to simulate the blank cooling during the hot stamping process. *International Journal of Material Forming*, 3(3), 147–163.
- Akhavan-Behabadi, M., Hekmatipour, F., Mirhabibi, S. and Sajadi, B. (2015). Experimental investigation of thermal–rheological properties and heat transfer behaviour of the heat transfer oil–copper oxide (HTO–CuO) nanofluid in smooth tubes. *Experimental Thermal and Fluid Science*, 68, 681-688.
- Altan, T. and Tekkaya, A. E. (2012). *Sheet Metal Forming Processes and Application*. New York: ASM International, 133–156.
- Amiri, A., Shanbedi, M., Yarmand, H., Arzani, H. K., Gharehkhani, S., Montazer, E., Sadri, R., Sarsam, W., Chew, B.T. and Kazi, S.N. (2015). Laminar convective heat transfer of hexylamine-treated MWCNTs-based turbine oil nanofluid. *Energy Conversion and Management*, 105, 355-367.
- Anoop, K., Sadr, R., Yu, J., Kang, S., Jeon, S. and Banerjee, D. (2012). Experimental study of forced convective heat transfer of nanofluids in a microchannel. *International Communications in Heat and Mass Transfer*, 39 (9), 1325-1330.
- Ansari, M. S., Shukla, S. and Awasthi, S. (2014). A review on nano fluid: Synthesis characterization and application. *Journal of Basic and Applied Engineering Research*, 1, 23-38.
- ANSYS. (2016). ANSYS Meshing. Retrieved from <http://www.ansys.com/products/platform/ansys-meshing> (11 JUNE 2017)
- Arani, A. A. and Amani, J. (2012). Experimental study on the effect of TiO₂–water nanofluid on heat transfer and pressure drop. *Experimental Thermal and Fluid Science*, 42, 107-115.

- Arulprakasajothi, M., Elangovan, K., Reddy, K.H. and Suresh, S. (2015b). Heat transfer study of water-based nanofluids containing titanium oxide nanoparticles. *Materials Today: Proceedings*, 2 (4), 3648-3655.
- ASHRAE. (2009). *ASHRAE Handbook - Fundamentals (SI Edition)*. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
- Azmi, W. H., Sharma, K. V., Mamat, R., Alias, A. B. S. and Izwan Misnon, I. (2012). Correlations for thermal conductivity and viscosity of water based nanofluids *IOP Conf. Series: Materials Science and Engineering*, 36, 1 - 6.
- Azmi, W. H., Sharma, K. V., Mamat, R., Najafi, G. and Mohamad, M. S. (2016). The enhancement of effective thermal conductivity and effective dynamic viscosity of nanofluids - A review. *Renewable and Sustainable Energy Reviews*, 53, 1046-1058.
- Azmi, W. H., Sharma, K. V., Sarma, P. K., Mamat, R. and Anuar, S. (2014). Comparison of convective heat transfer coefficient and friction factor of TiO₂ nanofluid flow in a tube with twisted tape inserts. *International Journal of Thermal Sciences*, 81(0), 84-93.
- Azmi, W. H., Sharma, K. V., Sarma, P. K., Mamat, R., Anuar, S. and Dharma Rao, V. (2013). Experimental determination of turbulent forced convection heat transfer and friction factor with SiO₂ nanofluid. *Experimental Thermal and Fluid Science*, 51 (0), 103-111.
- Banabic, D. (2010). *Sheet Metal Forming Processes*. 1st Edition. London: Springer.
- Bardelcik, A., Worswick, M. J., Winkler, S., and Wells, M. A. (2012). A strain rate sensitive constitutive model for quenched boron steel with tailored properties. *International Journal of Impact Engineering*, 50, 49-62.
- Bardelcik, A., Worswick, M. J., and Wells, M. A. (2014). The influence of martensite, bainite and ferrite on the as-quenched constitutive response of simultaneously quenched and deformed boron steel – Experiments and model, *Journal of Materials and Design*, 55, 509–525.
- Bayat, J. and Nikseresht, A. H. (2012). Thermal performance and pressure drop analysis of nanofluids in turbulent forced convective flows. *International Journal of Thermal Sciences*, 60, 236-243.

- Beck, M., Yuan, Y., Warrier, P. and Teja, A. (2010). The thermal conductivity of alumina nanofluids in water, ethylene glycol, and ethylene glycol + water mixtures. *Journal of Nanoparticle Research*, 12 (4), 1469-1477.
- Bhanvase, B. A., Sarode, M. R., Putterwar, L. A., K. A, A., Deosarkar, M. P. and Sonawane, S. H. (2014). Intensification of convective heat transfer in water/ethylene glycol based nanofluids containing TiO₂ nanoparticles. *Chemical Engineering and Processing: Process Intensification*, 82, 123-131.
- Bianco, V., Manca, O. and Nardini, S. (2014). Performance analysis of turbulent convection heat transfer of Al₂O₃ water-nanofluid in circular tubes at constant wall temperature. *Energy*, 77, 403-413.
- Boljanovic, V. and Paquin, J. (2006). *Die Design Fundamental*. 3rd Edition. Pennsylvania State University: Industrial Press
- Bolz, R. E. and Tuve, G. L. (2007). *Handbook of Tables for Applied Engineering Science*. 2nd Edition. Boca Raton: CRC press.
- Bosetti, P., Bruschi, S., Stoehr, T., Lechler, J., and Merklein, M. (2010). Interlaboratory comparison for heat transfer coefficient identification in hot stamping of high strength steels. *International Journal of Material Forming*, 3(S1), 817–820.
- Cabaleiro, D., Gracia-Fernández, C., Legido, J. and Lugo, L. (2015). Specific heat of metal oxide nanofluids at high concentrations for heat transfer. *International Journal of Heat and Mass Transfer*, 88, 872-879.
- Cengel, Y. A. and Ghajar, A. J. (2011). *Heat and Mass Transfer: In Fundamental and Application*, 4th Edition. New York: MacGraw Hill, pp. 9-16,25-28,423-426,488,489.
- Cengel, Y. A. (2010). *Fluid Mechanics*. 2nd Edition. New York: MacGraw Hill.
- Chandra Sekhara Reddy, M. and Vasudeva Rao, V. (2014). Experimental investigation of heat transfer coefficient and friction factor of ethylene glycol water based TiO₂ nanofluid in double pipe heat exchanger with and without helical coil inserts. *International Communications in Heat and Mass Transfer*, 50, 68-76.
- Chandrasekar, M., Suresh, S. and Bose, A. C. (2010a). Experimental investigations and theoretical determination of thermal conductivity and viscosity of Al₂O₃/water nanofluid. *Experimental Thermal and Fluid Science*, 34 (2), 210-216.

- Chandrasekar, M., Suresh, S. and Chandra Bose, A. (2010b). Experimental studies on heat transfer and friction factor characteristics of Al₂O₃/water nanofluid in a circular pipe under laminar flow with wire coil inserts. *Experimental Thermal and Fluid Science*, 34 (2), 122-130.
- Chang, Y., Meng, Z. H., Ying, L., Li, X. D., Ma, N. and Hu, P. (2011). Influence of hot press forming techniques on properties of vehicle high strength steels. *Journal of Iron and Steel Research International*, 18(5), 59–63.
- Choi, S. U. S., Zhang, Z. G. and Keblinski, P. (2004). (Nanofluids). In: Nalwa, S. H. (ed.) *Encyclopedia of Nanoscience and Nanotechnology*. New York: Scientific Publishers.
- Chun, S. Y., Bang, I. C., Choo, Y. J. and Song, C. H. (2011). Heat transfer characteristics of Si and SiC nanofluids during a rapid quenching and nanoparticles deposition effects. *International Journal of Heat and Mass Transfer*, 54 (5-6), 1217-1223.
- Cui, J., Sun, G., Xu, J., Huang, X. and Li, G. (2015). A method to evaluate the formability of high-strength steel in hot stamping. *Materials and Design*, 77, 95–109.
- Decagon Devices, I. (2014). *KD2 Pro Thermal Properties Analyzer Operator's Manual*. Pullman WA: Decagon Devices, Inc.
- Denkena, B., Helmecke, P. and Hülsemeyer, L. (2014). Energy Efficient Machining with Optimized Coolant Lubrication Flow Rates. *Procedia CIRP*, 24 (0), 25-31.
- Efevbokhan, V. E. and Ohiozua, O. N. (2013). Comparison of the cooling effects of a locally formulated car radiator coolant with water and a commercial coolant. *The International Journal Of Engineering And Science*, 2 (1), 254-262.
- Elias, M. M., Mahbubul, I. M., Saidur, R., Sohel, M. R., Shahrul, I. M., Khaleduzzaman, S. S. and Sadeghipour, S. (2014a). Experimental investigation on the thermophysical properties of Al₂O₃ nanoparticles suspended in car radiator coolant. *International Communications in Heat and Mass Transfer*, 54, 48-53.
- Esfe, M. H., Karimipour, A., Yan, W. M., Akbari, M., Safaei, M. R. and Dahari, M. (2015). Experimental study on thermal conductivity of ethylene glycol based nanofluids containing Al₂O₃ nanoparticles. *International Journal of Heat and Mass Transfer*, 88, 728-734.

- Fani, B., Kalteh, M. and Abbassi, A. (2015). Investigating the effect of Brownian motion and viscous dissipation on the nanofluid heat transfer in a trapezoidal microchannel heat sink. *Advanced Powder Technology*, 26 (1), 83-90.
- Fontes, D. H., Ribatski, G. and Bandarra Filho, E. P. (2015). Experimental evaluation of thermal conductivity, viscosity and breakdown voltage AC of nanofluids of carbon nanotubes and diamond in transformer oil. *Diamond and Related Materials*, 58, 115-121.
- Ganeshkumar, J., Kathirkaman, D., Raja, K., Kumaresan, V. and Velraj, R. (2015). Experimental study on density, thermal conductivity, specific heat and viscosity of water-ethylene glycol mixture dispersed with carbon nanotubes. *Thermal Science*, (00), 28-28.
- Gao, W., Kong, L. and Hodgson, P. (2012). Atomic interaction of functionalized carbon nanotube base nanofluids with a heating surface and its effect on heat transfer. *International Journal of Heat and Mass Transfer*, 55 (19-20), 5007-5015.
- George, R., Bardelcik, A. and Worswick, M. J. (2012). Hot forming of boron steels using heated and cooled tooling for tailored properties. *Journal of Materials Processing Technology*, 212(11), 2386–2399.
- Ghadimi, A., Saidur, R. and Metselaar, H. S. C. (2011). A review of nanofluid stability properties and characterization in stationary conditions. *International Journal of Heat and Mass Transfer*, 54 (17–18), 4051-4068.
- Hadadian, M., Samiee, S., Ahmadzadeh, H. and Goharshadi, E. K. (2013). Nanofluids for heat transfer enhancement—A review. *Physical Chemistry Research*, 1 (1), 1-33.
- Haddad, Z., Abid, C., Oztop, H. F. and Mataoui, A. (2014). A review on how the researchers prepare their nanofluids. *International Journal of Thermal Sciences*, 76 (0), 168-189.
- Hafizuddin. (2014). *Dies Design Structure & Manufacturing Concept*.
- Hajjar, Z., Rashidi, A. M. and Ghozatloo, A. (2014). Enhanced thermal conductivities of graphene oxide nanofluids. *International Communications in Heat and Mass Transfer*, 57, 128-131.

- Hatami, F. and Okhovati, F. (2014). Analysis of turbulent flow of nanofluids in a pipe. *European Online Journal of Natural and Social Sciences*, 3 (3), pp. 72-85.
- Hayduk, W. and Malik, V.K. (1971). Density, viscosity, and carbon dioxide solubility and diffusivity in aqueous ethylene glycol solutions. *Journal of Chemical & Engineering Data*, 16 (2), 143-146.
- Heris, S. Z., Shokrgozar, M., Poorpharhang, S., Shanbedi, M. and Noie, S. H. (2013). Experimental study of heat transfer of a car radiator with CuO/ethylene glycolwater as a coolant. *Journal of Dispersion Science and Technology*, 35 (5), 677-684.
- Heyhat, M. M., Kowsary, F., Rashidi, A. M., Momenpour, M. H. and Amrollahi, A. (2013). Experimental investigation of laminar convective heat transfer and pressure drop of water-based Al₂O₃ nanofluids in fully developed flow regime. *Experimental Thermal and Fluid Science*, 44, 483-489.
- Hoffmann, H., So, H. and Steinbeiss, H. (2007). Design of hot stamping tools with cooling system. *CIRP Annals - Manufacturing Technology*, 56(1), 269–272.
- Hu, P. and Ying, L. (2017). *Hot Stamping Advanced Manufacturing Technology of Lightweight Car Body*. 1st Edition. Beijing: Science Press.
- Hu, P., Ma, N., Liu, L. and Zhu, Y. (2013). *Theories, Methods and Numerical Technology of Sheet Metal Cold and Hot Forming*. 1st Edition. New York: Springer-Verlag London.
- Hung, Y. H., Teng, T. P. and Lin, B. G. (2013). Evaluation of the thermal performance of a heat pipe using alumina nanofluids. *Experimental Thermal and Fluid Science*, 44, 504-511.
- Hussein, A. M., Sharma, K. V., Bakar, R. A. and Kadirgama, K. (2014). A review of forced convection heat transfer enhancement and hydrodynamic characteristics of a nanofluid. *Renewable and Sustainable Energy Reviews*, 29, 734-743.
- Jarahnejad, M., Haghighi, E., Saleemi, M., Nikkam, N., Khodabandeh, R., Palm, B., Toprak, M. and Muhammed, M. (2015). Experimental investigation on viscosity of water-based Al₂O₃ and TiO₂ nanofluids. *Rheologica Acta*, 54 (5), 411-422.
- Javadi, F. S., Sadeghipour, S., Saidur, R., Boroumandjazi, G., Rahmati, B., Elias, M. M. and Soheli, M. R. (2013). The effects of nanofluid on thermophysical properties and heat transfer characteristics of a plate heat exchanger. *International Communications in Heat and Mass Transfer*, 44, 58-63.

- Jiang, C., Shan, Z., Zhuang, B., Zhang, M. and Xu, Y. (2012). Hot stamping die design for vehicle door beams using ultra-high strength steel. *International Journal of Precision Engineering and Manufacturing*, 13(7), 1101–1106.
- Kamalgharibi, M., Hormozi, F., Zamzamian, S. and Sarafraz, M. M. (2015). Experimental studies on the stability of CuO nanoparticles dispersed in different base fluids: influence of stirring, sonication and surface active agents. *Heat and Mass Transfer*, 52(1), 1-8.
- Karbasian, H. and Tekkaya, A. E. (2010). A review on hot stamping. *Journal of Materials Processing Technology*, 210(15), 2103–2118.
- Kayhani, M. H., Soltanzadeh, H., Heyhat, M. M., Nazari, M. and Kowsary, F. (2012). Experimental study of convective heat transfer and pressure drop of TiO₂/water nanofluid. *International Communications in Heat and Mass Transfer*, 39 (3), 456-462.
- Khedkar, R. S., Sonawane, S. S. and Wasewar, K. L. (2012). Influence of CuO nanoparticles in enhancing the thermal conductivity of water and monoethylene glycol based nanofluids. *International Communications in Heat and Mass Transfer*, 39 (5), 665-669.
- Kim, D. Y., Kim, H. Y., Lee, S. H., and Kim, H. K. (2015). Life estimation of hot press forming die by using interface heat transfer coefficient obtained from inverse analysis. *International Journal of Automotive Technology*, 16(2), 285–292.
- Kim, H. J., Lee, S. H., Lee, J. H. and Jang, S. P. (2015). Effect of particle shape on suspension stability and thermal conductivities of water-based bohemite alumina nanofluids. *Energy*, 90(2), 1290-1297.
- Kole, M. and Dey, T. K. (2011). Effect of aggregation on the viscosity of copper oxide–gear oil nanofluids. *International Journal of Thermal Sciences*, 50 (9), 1741-1747.
- Kole, M. and Dey, T. K. (2012a). Investigations on the pool boiling heat transfer and critical heat flux of ZnO-ethylene glycol nanofluids. *Applied Thermal Engineering*, 37, 112-119.
- Kole, M. and Dey, T. K. (2010). Thermal conductivity and viscosity of Al₂O₃ nanofluid based on car engine coolant. *Journal of Physics D: Applied Physics*, 43, 315501.

- Kole, M. and Dey, T. K. (2012b). Thermophysical and pool boiling characteristics of ZnO-ethylene glycol nanofluids. *International Journal of Thermal Sciences*, 62 (0), 61-70.
- Konakanchi, H., Vajjha, R. S., Chukwu, G. A. and Das, D. K. (2015). Measurements of μ h of three nanofluids and development of new correlations. *Heat Transfer Engineering*, 36 (1), 81-90.
- Kumaresan, V. and Velraj, R. (2012). Experimental investigation of the thermo-physical properties of water-ethylene glycol mixture based CNT nanofluids. *Thermochimica Acta*, 545, 180-186.
- Kumar, D. D., Shirsat, V. Sharma, V. and Sarpate, C. (2011). Design optimization of hot forming tools by numerical thermal analysis. *KLT Automotive and Tubular Product LTD*.
- Li, H., He, Y., Hu, Y., Jiang, B. and Huang, Y. (2015). Thermophysical and natural convection characteristics of ethylene glycol and water mixture based ZnO nanofluids. *International Journal of Heat and Mass Transfer*, 91, 385-389.
- Li, Y., Fernández-Seara, J., Du, K., Pardiñas, Á. Á., Latas, L. L. and Jiang, W. (2016). Experimental investigation on heat transfer and pressure drop of ZnO/ethylene glycol-water nanofluids in transition flow. *Applied Thermal Engineering*, 93, 537-548.
- Lim, S. K., Azmi, W. H. and Yusoff, A. R. (2016). Investigation of thermal conductivity and viscosity of Al₂O₃/water-ethylene glycol mixture nanocoolant for cooling channel of hot press forming die application. *International Communications in Heat and Mass Transfer*, 78, 182-189.
- Lim, W. S., Choi, H. S., Ahn, S. Y. and Kim, B. M. (2014). Cooling channel design of hot stamping tools for uniform high-strength components in hot stamping process. *International Journal of Advanced Manufacturing Technology*, 70(5-8), 1189–1203.
- Lin, T., Song, H., Zhang, S., Cheng, M. and Liu, W. (2014). Cooling systems design in hot stamping tools by a thermal-fluid-mechanical coupled approach. *Advances in Mechanical Engineering*, 2, 1–13.
- Liu, H., Lei, C. and Xing, Z. (2013). Cooling system of hot stamping of quenchable steel BR1500HS: optimization and manufacturing methods. *The International Journal of Advanced Manufacturing Technology*, 69(1-4), 211–223.

- Liu, M. S., Lin, M. C. C., Tsai, C. Y. and Wang, C. C. (2006). Enhancement of thermal conductivity with Cu for nanofluids using chemical reduction method. *International Journal of Heat and Mass Transfer*, 49 (17–18), 3028-3033.
- Löbbecke, C., Hering, O., Hiegemann, L., and Tekkaya, A. E. (2016). Setting mechanical properties of high strength steels for rapid hot forming processes. *Materials*, 9(4), 229.
- Madhesh, D. and Kalaiselvam, S. (2014). Experimental study on the heat transfer and flow properties of Ag–ethylene glycol nanofluid as a coolant. *Heat and Mass Transfer*, 50 (11), 1597-1607.
- Maeno, T., Mori, K. and Nagai, T. (2014). Improvement in formability by control of temperature in hot stamping of ultra-high strength steel parts. *CIRP Annals - Manufacturing Technology*, 63(1), 301–304.
- Mahbubul, I. M., Saidur, R. and Amalina, M. A. (2012). Latest developments on the viscosity of nanofluids. *International Journal of Heat and Mass Transfer*, 55 (4), 874-885.
- Maheshwary, P. and Nemade, K. (2015). Enhancement in heat transfer performance of $\text{ZrO}_2/\text{H}_2\text{O}$ nanofluid via ultrasonication time. *International Journal on Recent and Innovation Trends in Computing and Communication*, 3 (2), 035– 037.
- Mahian, O., Kianifar, A. and Wongwises, S. (2013). Dispersion of ZnO nanoparticles in a mixture of ethylene glycol–water, exploration of temperature-dependent density, and sensitivity analysis. *Journal of Cluster Science*, 24 (4), 1103-1114.
- Mariano, A., Pastoriza-Gallego, M. J., Lugo, L., Camacho, A., Canzonieri, S. and Piñeiro, M. M. (2013). Thermal conductivity, Rheological behaviour and density of non-Newtonian ethylene glycol based SnO_2 nanofluids. *Fluid Phase Equilibria*, 337, 119-124.
- Mariano, A., Pastoriza-Gallego, M. J., Lugo, L., Mussari, L. and Piñeiro, M. M. (2015). CO_3O_4 ethylene glycol-based nanofluids: Thermal conductivity, viscosity and high pressure density. *International Journal of Heat and Mass Transfer*, 58, 54-60.
- Melissa, B. (2012). Fluid Flow Rates. Retrieved from <http://www.education.com/science-fair/article/fluid-flow-rates/> (22 JUNE 2016)

- Merklein, M., Johannes, M., Lechner, M., and Kuppert, A. (2014). A review on tailored blanks - Production, applications and evaluation. *Journal of Materials Processing Technology*, 214(2), 151–164.
- Misumi. (2015). Misumi Press Stock Booklet 2015.
- Mojarrad, M. S., Keshavarz, A., Ziabasharhagh, M. and Raznahan, M. M. (2014). Experimental investigation on heat transfer enhancement of alumina/water and alumina/water–ethylene glycol nanofluids in thermally developing laminar flow. *Experimental Thermal and Fluid Science*, 53, 111-118.
- Mori, K., Maeno, T. and Maruo, Y. (2012). Punching of small hole of die-quenched steel sheets using local resistance heating. *CIRP Annals - Manufacturing Technology*, 61(1), 255–258.
- Mori, K., Maeno, T., Yamada, H., & Matsumoto, H. (2015). International Journal of Machine Tools & Manufacture 1-Shot hot stamping of ultra-high strength steel parts consisting of resistance heating, forming , shearing and die quenching. *International Journal of Machine Tools and Manufacture*, 89, 124–131.
- Motahar, S., Nikkam, N., Alemrajabi, A. A., Khodabandeh, R., Toprak, M. S. and Muhammed, M. (2014). A novel phase change material containing mesoporous silica nanoparticles for thermal storage: A study on thermal conductivity and viscosity. *International Communications in Heat and Mass Transfer*, 56, 114-120.
- Naderi, M. (2007). *Hot Stamping of Ultra High Strength Steels* (PhD Thesis) RWTH Aachen University, Germany.
- Naderi, M., Ketabchi, M., Abbasi, M. and Bleck, W. (2011). Analysis of microstructure and mechanical properties of different high strength carbon steels after hot stamping. *Journal of Materials Processing Technology*, 211(6), 1117–1125.
- Naganathan, A. (2010). *Hot Stamping of Manganese Boron Steel* (PhD Thesis) The Ohio State University, America.
- Naganathan, A. and Penter, L. (2012). Hot Stamping. *In Sheet Metal Forming-Processes and Applications*, pp. 133–156.

- Namburu, P. K., Kulkarni, D. P., Misra, D. and Das, D. K. (2007). Viscosity of copper oxide nanoparticles dispersed in ethylene glycol and water mixture. *Experimental Thermal and Fluid Science*, 32 (2), 397-402.
- Namklang, P. and Uthaisangsuk, V. (2016). Description of microstructures and mechanical properties of boron alloy steel in hot stamping process. *Journal of Manufacturing Processes*, 21, 87–100.
- Nikkam, N., Haghighi, E. B., Saleemi, M., Behi, M., Khodabandeh, R., Muhammed, M., Palm, B. and Toprak, M. S. (2014). Experimental study on preparation and base liquid effect on thermo-physical and heat transport characteristics of α -SiC nanofluids. *International Communications of Heat and Fluid Flow*, 55, 38-44.
- Nuraini, A. and Aqida, S. N. (2013). Optimization of quenching process in hot press forming of 22MnB5 steel for high strength properties. *ICMER International Conference on Mechanical Engineering Research*, (50), 012064
- Pak, B. C. and Cho, Y. I. (1998). Hydrodynamic and heat transfer study of dispersed fluids with submicron metallic oxide particles. *Experimental Heat Transfer*, 11 (2), 151-170.
- Pang, C., Jung, J. Y., Lee, J. W. and Kang, Y. T. (2012). Thermal conductivity measurement of methanol-based nanofluids with Al_2O_3 and SiO_2 nanoparticles. *International Journal of Heat and Mass Transfer*, 55 (21), 5597-5602.
- Parekh, K. and Lee, H. S. (2010). Magnetic field induced enhancement in thermal conductivity of magnetite nanofluid. *Journal of Applied Physics*, 107 (9), 09A310.
- Pastoriza-Gallego, M., Lugo, L., Legido, J. and Piñeiro, M. (2011). Thermal conductivity and viscosity measurements of ethylene glycol based Al_2O_3 nanofluids. *Nanoscale Research Letters*, 6 (1), 1-11.
- Peyghambarzadeh, S., Hashemabadi, S., Hoseini, S. and Seifi Jamnani, M. (2011a). Experimental study of heat transfer enhancement using water/ethylene glycol based nanofluids as a new coolant for car radiators. *International Communications in Heat and Mass Transfer*, 38 (9), 1283-1290.
- Qu, J., Wu, H. Y. and Cheng, P. (2010). Thermal performance of an oscillating heat pipe with Al_2O_3 –water nanofluids. *International Communications in Heat and Mass Transfer*, 37 (2), 111-115.

- Ravikumar, S. V., Haldar, K., Jha, J. M., Chakraborty, S., Sarkar, I., Pal, S. K. and Chakraborty, S. (2015). Heat transfer enhancement using air-atomized spray cooling with water–Al₂O₃ nanofluid. *International Journal of Thermal Sciences*, 96, 85-93.
- Reddy, M. C. S. and Rao, V. V. (2013). Experimental studies on thermal conductivity of blends of ethylene glycol-water-based TiO₂ nanofluids. *International Communications in Heat and Mass Transfer*, 46, 31-36.
- Said, Z., Sajid, M. H., Alim, M. A., Saidur, R. and Rahim, N. A. (2013). Experimental investigation of the thermophysical properties of Al₂O₃-nanofluid and its effect on a flat plate solar collector. *International Communications in Heat and Mass Transfer*, 48 (0), 99-107.
- Salman, B., Mohammed, H. and Kherbeet, A. S. (2014). Numerical and experimental investigation of heat transfer enhancement in a microtube using nanofluids. *International Communications in Heat and Mass Transfer*, 59, 88-100.
- Samira, P., Saeed, Z., Motahare, S. and Mostafa, K. (2015). Pressure drop and thermal performance of CuO/ethylene glycol (60%)-water (40%) nanofluid in car radiator. *Korean Journal of Chemical Engineering*, 32 (4), 609-616.
- Sarafraz, M., Hormozi, F. and Kamalgharibi, M. (2014). Sedimentation and convective boiling heat transfer of CuO-water/ethylene glycol nanofluids. *Heat and Mass Transfer*, 50 (9), 1237-1249.
- Sekhar, Y. R. and Sharma, K. (2015). Study of viscosity and specific heat capacity characteristics of water-based Al₂O₃ nanofluids at low particle concentrations. *Journal of Experimental Nanoscience*, 10 (2), 86-102.
- Serebryakova, M., Dimov, S., Bardakhanov, S. and Novopashin, S. (2015). Thermal conductivity, viscosity and rheology of a suspension based on Al₂O₃ nanoparticles and mixture of 90% ethylene glycol and 10% water. *International Journal of Heat and Mass Transfer*, 83, 187-191.
- Sereelakshmy, K. R., Aswathy, S. N., Vidhya, K. M., Saranya, T. R. and Sreeja, C. N. (2014). Review Article - An overview of recent nanofluids research. *International Research Journal of Pharmacy*, 5 (4), 239-234.
- Sever, N. K., Mete, O. H., Demiralp, Y., Choi, C. and Altan, T. (2012). Springback prediction in bending of AHSS-DP 780. In *NAMRI/SME*, Vol. 40.

- Sharma, K. V., Sarma, P. K., Azmi, W. H., Noor, M. M., Kadirgama, K. and Mamat, R. (2009). Validation of turbulent flow heat transfer data of water based nanofluids. *18 International Conference on Composites/Nano Engineering*, pp. 3606-3612.
- Shegokar, R. and Müller, R. H. (2010). Nanocrystals: Industrially feasible multifunctional formulation technology for poorly soluble actives. *International Journal of Pharmaceutics*, 399 (1–2), 129-139.
- Sheikhbahai, M., Nasr Esfahany, M. and Etesami, N. (2012). Experimental investigation of pool boiling of Fe₃O₄/ethylene glycol–water nanofluid in electric field. *International Journal of Thermal Sciences*, 62, 149-153.
- Sidik, N. A. C., Mohammed, H. A., Alawi, O. A. and Samion, S. (2014). A review on preparation methods and challenges of nanofluids. *International Communications in Heat and Mass Transfer*, 54, 115-125.
- Sidik, N. A. C., Yazid, M. N. A. W. M. and Mamat, R. (2015). A review on the application of nanofluids in vehicle engine cooling system. *International Communications in Heat and Mass Transfer*, 68, 85-90.
- Sigma-Aldrich 2015. (Aluminium oxide - Safety data sheet for Product No. 718475 [online]). 19 June 2015 editions.
- Skrikerud, M., Megahed, M., & Porzner, H. (2010). Simulation of Hot Stamping Process.
- So, H., Faßmann, D., Hoffmann, H., Golle, R. and Schaper, M. (2012). An investigation of the blanking process of the quenchable boron alloyed steel 22MnB5 before and after hot stamping process. *Journal of Materials Processing Technology*, 212(2), 437–449.
- Sonawane, S. S., Khedkar, R. S. and Wasewar, K. L. (2015). Effect of sonication time on enhancement of effective thermal conductivity of nano TiO₂–water, ethylene glycol, and paraffin oil nanofluids and models comparisons. *Journal of Experimental Nanoscience*, 10 (4), 310-322.
- Srithananan, P., Kaewtatip, P., and Uthaisangsuk, V. (2016). Materials Science & Engineering A Micromechanics-based modeling of stress – strain and fracture behaviour of heat-treated boron steels for hot stamping process. *Materials Science & Engineering A*, 667, 61–76.

- Strandberg, R. and Das, D. K. (2010). Finned tube performance evaluation with nanofluids and conventional heat transfer fluids. *International Journal of Thermal Sciences*, 49 (3), 580-588.
- Suganthi, K. and Rajan, K. (2012a). Temperature induced changes in ZnO–water nanofluid: zeta potential, size distribution and viscosity profiles. *International Journal of Heat and Mass Transfer*, 55 (25), 7969-7980.
- Suganthi, K. and Rajan, K. (2014). A formulation strategy for preparation of ZnO–propylene glycol–water nanofluids with improved transport properties. *International Journal of Heat and Mass Transfer*, 71, 653-663.
- Suganthi, K. S. and Rajan, K. S. (2012b). Temperature induced changes in ZnO–water nanofluid: Zeta potential, size distribution and viscosity profiles. *International Journal of Heat and Mass Transfer*, 55 (25–26), 7969-7980.
- Sundar, L. S. and Singh, M. K. (2013). Convective heat transfer and friction factor correlations of nanofluid in a tube and with inserts: A review. *Renewable and Sustainable Energy Reviews*, 20, 23-35.
- Sundar, L. S., Farooky, M. H., Sarada, S. N. and Singh, M. (2013a). Experimental thermal conductivity of ethylene glycol and water mixture based low volume concentration of Al₂O₃ and CuO nanofluids. *International Communications in Heat and Mass Transfer*, 41, 41-46.
- Sundar, L. S., Sharma, K. V., Naik, M. T. and Singh, M. K. (2013b). Empirical and theoretical correlations on viscosity of nanofluids: A review. *Renewable and Sustainable Energy Reviews*, 25 (0), 670-686.
- Sundar, L. S., Singh, M. K. and Sousa, A. C. M. (2013c). Thermal conductivity of ethylene glycol and water mixture based Fe₃O₄ nanofluid. *International Communications in Heat and Mass Transfer*, 49 (0), 17-24.
- Sundar, L. S., Venkata Ramana, E., Singh, M. K. and Sousa, A. C. M. (2014). Thermal conductivity and viscosity of stabilized ethylene glycol and water mixture Al₂O₃ nanofluids for heat transfer applications: An experimental study. *International Communications in Heat and Mass Transfer*, 56, 86-95.
- Suresh, S., Chandrasekar, M., Selvakumar, P. and Page, T. (2012). Experimental studies on heat transfer and friction factor characteristics of Al₂O₃/water nanofluid under laminar flow with spiralled rod inserts. *International Journal of Nanoparticles*, 5 (1), 37-55.

- Suresh, S., Venkitaraj, K. P., Selvakumar, P. and Chandrasekar, M. (2011). Synthesis of Al_2O_3 -Cu/water hybrid nanofluids using two step method and its thermo physical properties. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 388 (1–3), 41-48.
- Taha, Z., Yusoff, A. R., Farid, M., Sharif, M., Saharudin, M. A. H., & Zamri, M. F. (2014). Comparison of Cooling Performance Between High Thermal Conductivity Steel (HTCS 150) and Hot Work Tool Steel (SKD 61) Insert for Experimental Tool Using Finite Element Analysis. *Advanced Materials Research* 903, 163–168.
- Tajik, B., Abbassi, A., Saffar-Avval, M. and Najafabadi, M. A. (2012). Ultrasonic properties of suspensions of TiO_2 and Al_2O_3 nanoparticles in water. *Powder Technology*, 217, 171-176.
- Teng, T. P. (2013). Thermal conductivity and phase-change properties of aqueous alumina nanofluid. *Energy Conversion and Management*, 67 (0), 369-375.
- Teng, T. P. and Hung, Y. H. (2012). Estimation and experimental study of the density and specific heat for alumina nanofluid. *Journal of Experimental Nanoscience*, 9 (7), 707-718.
- Teng, T. P., Hung, Y. H., Teng, T. C., Mo, H. E. and Hsu, H. G. (2010). The effect of alumina/water nanofluid particle size on thermal conductivity. *Applied Thermal Engineering*, 30 (14–15), 2213-2218.
- Thanadngarn, C., Sirivedin, K., Engineering, M., Thai-german, T. S. I., Buakaew, V., Neamsup, Y. (2013). The study of the springback effect in the UHSS by U-bending process, 6, 19–25.
- Timofeeva, E. V. (2011). Nanofluids for heat transfer–potential and engineering strategies. *Two Phase Flow, Phase Change and Numerical Modelling*, 435-450.
- Timofeeva, E. V., Moravek, M. R. and Singh, D. (2011a). Improving the heat transfer efficiency of synthetic oil with silica nanoparticles. *Journal of colloid and interface science*, 364 (1), 71-79.
- Timofeeva, E. V., Yu, W., France, D. M., Singh, D. and Routbort, J. L. (2011b). Base fluid and temperature effects on the heat transfer characteristics of SiC in ethylene glycol/ H_2O and H_2O nanofluids. *Journal of Applied Physics*.

- Tondini, F., Bosetti, P. and Bruschi, S. (2011). Heat transfer in hot stamping of high-strength steel sheets. *Journal of Engineering Manufacture*, 225, 1813–1824.
- Tony John and Krishnakumar, T. S. (2013). Experimental studies of thermal conductivity, viscosity and stability of ethylene glycol nanofluids. *International Conference on Energy and Environment - 2013 (ICEE 2013)*, 2(1), pp. 611-617.
- Vajjha, R. S., Das, D. K. and Kulkarni, D. P. (2010a). Development of new correlations for convective heat transfer and friction factor in turbulent regime for nanofluids. *International Journal of Heat and Mass Transfer*, 53 (21-22), 4607-4618.
- Vajravelu, K., Prasad, K. V. and NG, C. O. (2013). The effect of variable viscosity on the flow and heat transfer of a viscous Ag-water and Cu-water nanofluids. *Journal of Hydrodynamics, Ser. B*, 25 (1), 1-9.
- Wang, S. and Lee, P. (2013). Investigation of die quench properties of hot stamping. *China Steel Technical Report*, 2(26), 22–31.
- Wei, X. and Wang, L. (2010). Synthesis and thermal conductivity of microfluidic copper nanofluids. *Particuology*, 8 (3), 262-271.
- Wong, K. V. and De Leon, O. (2010). Applications of nanofluids: current and future. *Advances in Mechanical Engineering*, 2, 519659.
- Wu, J. M. and Zhao, J. (2013). A review of nanofluid heat transfer and critical heat flux enhancement—Research gap to engineering application. *Progress in Nuclear Energy*, 66 (0), 13-24.
- Xiaoda, L., Xiangkui, Z., Ping, H. and Xianghui, Z. (2016). Thermo-mechanical coupled stamping simulation about the forming process of high-strength steel sheet. *International Journal of Control and Automation*, 9(1), 93–102.
- Xie, H., Li, Y. and Yu, W. (2010). Intriguingly high convective heat transfer enhancement of nanofluid coolants in laminar flows. *Physics Letters A*, 374 (25), 2566-2568.
- Yang, X. F. and Liu, Z. H. (2011). Pool boiling heat transfer of functionalized nanofluid under sub-atmospheric pressures. *International Journal of Thermal Sciences*, 50 (12), 2402-2412.

- Yiamsawas, T., Mahian, O., Dalkilic, A. S., Kaewnai, S. and Wongwises, S. (2013). Experimental studies on the viscosity of TiO_2 and Al_2O_3 nanoparticles suspended in a mixture of ethylene glycol and water for high temperature applications. *Applied Energy*, 111, 40-45.
- Yu, W. and Xie, H. (2012). A review on nanofluids: preparation, stability mechanisms, and applications. *Journal of Nanomaterials*, 2012, 1.
- Yu, W., Xie, H., Chen, L. and Li, Y. (2010). Investigation on the thermal transport properties of ethylene glycol-based nanofluids containing copper nanoparticles. *Powder Technology*, 197 (3), 218-221.
- Yu, W., Xie, H., Li, Y., Chen, L. and Wang, Q. (2012). Experimental investigation on the heat transfer properties of Al_2O_3 nanofluids using the mixture of ethylene glycol and water as base fluid. *Powder Technology*, 230, 14-19.
- Zakaria, I., Azmi, W. H., Mohamed, W. A. N. W., Mamat, R. and Najafi, G. (2015). Experimental investigation of thermal conductivity and electrical conductivity of Al_2O_3 nanofluid in water-ethylene glycol Mixture for proton exchange membrane fuel cell application. *International Communications in Heat and Mass Transfer*, 61, 61-68.
- Zamri, M. F. (2017) *Heuristic Optimization of Cooling Channel Design for Hot Stamping Tool Process* (MSc. Thesis) Universiti Malaysia Pahang, Malaysia.
- Zhang, Z., Li, X., Pan, L. and Wei, X. (2010). Numerical Simulation on Hot Forming of B Pillar.
- Zhang, Z., Li, X., Zhao, Y. and Li, X. (2014). Heat transfer in hot stamping of high-strength boron steel sheets. *Metallurgical and Materials Transactions B: Process Metallurgy and Materials Processing Science*, 45(4), 1192–1195.
- Zhong-De, S., Mi-Ian, Z., Chao, J., Ying, X. and Wem-Juan, R. (2010). Basic study on die cooling system of hot stamping process. *International Conference on Advanced Technology of Design and Manufacture*, 67(2), 5–8.
- Zhu, D., Li, X., Wang, N., Wang, X., Gao, J. and Li, H. (2009). Dispersion behavior and thermal conductivity characteristics of Al_2O_3 - H_2O nanofluids. *Current Applied Physics*, 9 (1), 131-139.